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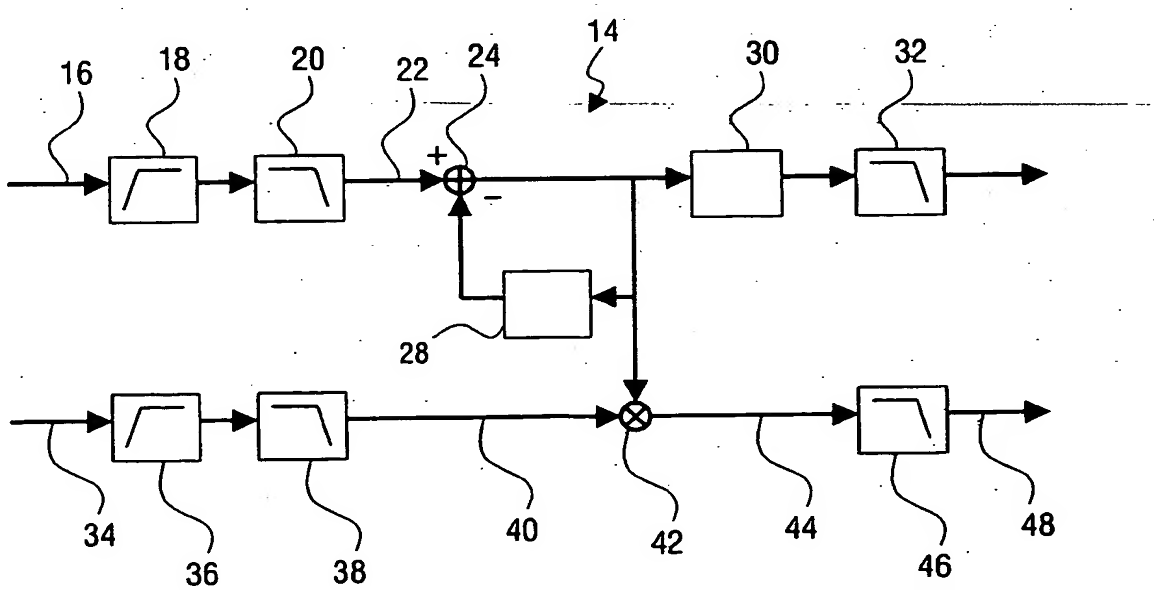
(54) Title: APPARATUS AND RELATED METHOD FOR MONITORING TRACKING OF AN OPTICAL DISC



(57) Abstract: A differential phase detection arrangement for a differential phase detection arrangement for monitoring the tracking of an optical disk, comprising a four-quadrant photo detector from which first and second signals are derived, phase shift or differentiating means arranged for phase shifting or differentiating the first of the photo detector signals, multiplying means arranged for multiplying the phase shifted or differentiated signal with the second of the said photo detector signals so as to produce a signal for deriving a Differential Phase Detection signal.

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DESCRIPTION

APPARATUS AND RELATED METHOD FOR MONITORING TRACKING OF AN OPTICAL DISC

The present invention relates to an apparatus and related method for monitoring tracking of an optical disc.

When monitoring radial tracking in an optical disc system, conventionally a radial push-pull signal is adopted within the optical disc system and which is based upon the detection of DC light balance within the optical transducer. However this signal is sensitive to errors, such as the beam landing effects arising from detector displacement.

Typically, Differential Phase Detection (DPD), and also Differential Time Detection (DTD), have been widely adopted as schemes for deriving an improved optical radial tracking error signal for optical disc systems such as CD, DVD and blue-ray optical disc systems.

The present invention relates in particular to a new method and arrangement of DPD for use in particular within such systems.

Known DPD and DTD systems have been introduced in an attempt to improve on the known conventional radial push-pull base systems since the detection offered by such methods arises in the AC domain where the potential offsets have a lesser effect on tracking and monitoring as compared with the DC domain.

Figure 1 is an illustration of a standard four-quadrants photo detector employed within a DPD system and in which a signal is produced in accordance with the manner in which a reflected light beam 12 impinges on the four quadrants A, B, C, D of the photo detector 10 so as to produce currents at each of those photo detector quadrants A, B, C and D.

In current DPD systems the conventional DPD signals are obtained from the detector currents arising from the four quadrants A, B, C, D, whose phase is unaffected by the radial tracking error. Such signals are the RF

signal derived from the combination $I_A+I_B+I_C+I_D$ and also the tangential push-pull signal derived from $I_A+I_C-I_B-I_D$. Additionally, such known DPD signals have been derived from detector currents whose phase is strongly affected by the radial tracking error such as the radial push-pull signal arising from $I_A+I_B-I_C-I_D$, and the diagonal push-pull signal $I_A+I_D-I_B-I_C$.

However, conventional DPD methods and arrangements suffer disadvantageous limitations particularly with regard to cost implications, complexity and limitations in performance.

The present invention seeks to provide for an apparatus and method for monitoring tracking of an optical disc having advantages over known such apparatus and methods.

According to one aspect of the present invention there is provided a differential phase detection arrangement for monitoring the tracking of an optical disc, comprising a four-quadrant photo detector from which first and second signals are delivered, phase shift or differentiating means arranged for phase shifting or differentiating the first of the photo detector signals, multiplying means arranged for multiplying the phase shifted or differentiated signal with the second of the said photo detector signals so as to produce a signal for deriving a Differential Phase Detection signal.

The invention is advantageous in providing for a decrease in cost, simplification of the optical disc system and increased performance.

The feature of Claim 2 is advantageous in providing a particularly robust implementation of the invention.

A particular advantage of the invention, and in accordance with the features of Claims 6 and 7, is that only two high frequency analogue-digital-converters are required and this serves to enhance the advantages discussed above.

Further, the features of Claims 8-14 are particularly advantageous in providing for an embodiment in limiting the effect of beam landing and

defocusing such that off-set errors arising from beam landing and defocusing will not arise.

According to another aspect of the present invention there is provided a method of monitoring tracking in an optical disc drive comprising the steps of deriving signals from a four quadrants photo detector, phase shifting or differentiating a first of the said signals derived from the photo detector, multiplying the resulting phase shifted or differentiated band pass signal with a second of the said signals derived from the photo detector so as to arrive at a DPD signal.

Yet further, the differential phase detection arrangement embodying the present invention can advantageously be arranged for use in association with separate digitized signals comprising normalized signals.

In particular, the sum of the outputs from diagonal opposite pairs of the four-quadrant photo-detector can advantageously be employed to control the signal output from each quadrant within the diagonally opposite pair of quadrants.

On this basis, a normalization method for individual diagonal signals can be provided so as to compensate for, or remove, unwanted amplitude changes of the signals from the diagonal quadrants for example caused by hair-scratched type defects and so this can further enhance the performance of the radial tracking DPD signal.

Of course, it will be appreciated that the method of the present invention can also be arranged so as to include the step of normalising the separate digitized signals.

The invention is described further hereinafter, by way of example only, with reference to the accompanying drawings in which:

Fig. 1 is a schematic view of a four quadrants photo detector employed within a DPD system;

Fig. 2 is a schematic block diagram of an arrangement implementing a first embodiment of the present invention;

Fig. 3 is a schematic block diagram of an arrangement implementing a second embodiment of the present invention; and

Fig. 4 is a schematic block diagram of an arrangement implementing a third embodiment of the present invention.

Turning first to Fig. 2, there is illustrated an arrangement 14 for providing a DPD signal and related slope signal that can be arranged to normalise the DPD signal in accordance with an embodiment of the present invention.

A digitized RF signal (A+B+C+D) 16 is derived from a four quadrants photo detector, such as that illustrated in Fig. 1, via an analogue-digital converter, and delivered to a band-pass arrangement comprising a high pass filter 18 and a low pass filter 20. The resulting band-pass signal 22 is then delivered to a 90° phase shift arrangement, or differentiating arrangement 24, 26, 28 so as to provide for, for example, an absolute differentiated function 30 which is delivered to a further low pass filter 32 so as to provide for the slope signal which, as noted above, can be arranged to normalise the DPD signal.

In order to arrive at the DPD signal, a further input signal 34 is derived from a digitized diagonal push-pull digitized signal (A+C-B-D) derived from the four quadrants photo detector and which is then delivered through a band-pass arrangement comprising a high pass filter 36 and a low pass filter 38. The resulting band-pass signal 40 is then multiplied by the differentiated function 30 within a multiplication unit 42, and the resulting signal 44, once filtered by way of the low pass filter 46, provides for the DPD signal 48. As mentioned previously, the slope signal derived from the low pass filter 32, can be arranged to normalise the DPD signal 48.

The cut-off frequency of the high pass filters 18, 36 advantageously is not higher than the frequency of I14 i.e. modulated frequency by the largest mark and space lengths; whereas the cut-off frequency of the low pass filters 20, 38 is advantageously not lower than the frequency of I3 or I2 i.e. modulated frequency by the smallest mark and space lengths.

Turning now to Fig. 3, there is illustrated a further embodiment of the present invention.

Although a particular advantage of the arrangement illustrated in Fig. 2 is that only two high frequency analogue digital converters are required compared with that of the following embodiment, a track offset error may be introduced in the DPD signal achieved in accordance with the embodiment of Fig. 2 due to the effect of beam landing and defocusing.

The embodiment illustrated in accordance with Fig. 3 and as outlined below is further advantageous in that it does not suffer an offset error due to the effect of beam landing and defocusing.

Turning now to Fig. 3, it will be appreciated that the arrangement receives discrete input signals from the analogue digital converters associated with each of the quadrants A, B, C, D of a four-quadrant photo detector such as that illustrated in Fig. 1. Quadrant A delivers signal 50, quadrant D delivers signal 52, quadrant B delivers signal 54 and quadrant C delivers signal 56.

As illustrated in Fig. 3, signal 50 is delivered to an adder 58 where it is added to the signal 52 and the combined signal then delivered through a band-pass arrangement comprising a high pass filter 60 and a low pass filter 62. The resulting signal 64 is then phase shifted by 90 degrees or differentiated, by a phase shift/differentiating arrangement 66, 68, 70 so as to provide for the phase shifted/differentiated signal 72. The signal 52 derived from the analogue digital converter of detector quadrant D is, in addition to being delivered to the adder 58, delivered to a subtraction unit 74 from where the resulting signal is delivered to a band-pass arrangement comprising a high pass filter 76 and low pass filter 78. The band pass signal 80 obtained from the filters 76,78 is then delivered to a multiplication unit where it is multiplied with the phase shifted differentiated signal 72. The signal resulting from this multiplication comprises signal 84.

The arrangement relating to the signals 54, 56 from detector quadrants B and C is similar to that arising in relation to the signals 50, 52 in that the signals 54, 56 are combined at adder 86 and delivered to a band-pass filter arrangement comprising a high pass filter 88 and low pass filter 90 with a

resulting signal 92 being phase shifted by 90 degrees, or differentiated, by means of the phase shift/differentiation unit 94, 96, 98.

The differentiated signal is then multiplied at 114 by a signal 112 resulting from a subtracting unit 106, and a band pass filter arrangement comprising high pass filter 108 and low pass filter 110. The resulting signal 116 is then delivered to a subtracting unit 118. Where a difference between the two signals 84, 116 resulting from the multiplication of the differentiated signals with the undifferentiated signals is determined. The resulting difference signal is then delivered via a low pass filter 120 so as to provide for the DPD signal 122.

As with the embodiment of Fig. 2, a slope signal is also derived from combinations of the input signals. That is, the phase shifted/differentiated signals from the band pass filter arrangement 60, 62 and 88, 90 are added at 100 to provide, for example, for an absolute differentiated function 102 which is delivered to a further low pass filter 104 so as to provide a slope signal for normalizing the DPD signal 122.

The setting for the cut-off filters of the band pass filter arrangements in Fig. 3 can be the same as those discussed in relation to the embodiment illustrated in Fig. 2.

Turning now to Fig. 4, there is illustrated in block diagrammatic form another embodiment of the present invention. In this particular illustrated embodiment, the said arrangement is again arranged to receive signals 124, 126, 128 and 130 from four quadrants A, C, B and D of a four-quadrant photo detector and each of which signals is delivered to a respective band-pass filter arrangement 132, 134, 136 and 138.

The band-pass filtered signals from quadrants A and C are combined by means of an adder 140, whereas the band-pass filtered signals from quadrants B and D are added by means of an adder 142.

The resulting signal from the adder 140 is differentiated by differentiating means 144 and an absolute value of this is derived at 146 and then delivered to a low pass filtering means 148. The slope signal then derived from the low pass filter and normalization means 150 are employed

such that the signal from quadrant A is effectively normalized by the slope signal derived from the low pass filtering means 148 so as to arrive at a normalized value A_N value of the signal 124 from the quadrant A.

The signal 126 from quadrant C is likewise normalized at 152 by application of the slope signal derived from the low pass filtering means 148 so as to provide for a normalized value C_N.

The processing of the signals 128, 130 from the quadrants B and D of the four quadrant photo detector is conducted in a similar manner as that described above but in relation to differentiating means 154 and the means 156, 158 for determining an absolute low pass filtered slope signal for the signals from the quadrants B, D. Likewise, the slope signal is applied at 160 and 162 respectively to the signals 128 and 130 respectively from the two quadrants B and D so as to arrive at normalized values B_N and D_N for those signals.

The normalized signals A_N and B_N from the quadrants A and B are then combined at adder 164 and the resulting value differentiated by difference determining means 166 so as to arrive at a differentiated value of the combined normalized values of the signals for quadrants A and B.

The difference between the normalized values A_N and B_N is determined at a subtraction unit 170 and the resulting signal multiplied by the differentiated value 168 of the combined normalized values A_N and B_N.

The result of this multiplication is delivered from multiplication unit 172 to a subtraction unit 182.

Also delivered to the subtraction unit 182 is a signal derived from the multiplication of the differentiated value of the combined normalized values of the signals from quadrants D and C and as obtained by way of an adder 174 and differentiating arrangement 176.

The signal 178 obtained is multiplied by the difference between the normalized values of the signals from the quadrants D and C and as obtained by way of subtraction unit 180. This provides a signal multiplied at the multiplier 184 which is compared at subtraction unit 182 with the signal

obtained from the multiplier 174 so as to provide an output DPD signal by means of a low pass filtering arrangement 186.

In further consideration of Fig. 4, it should be appreciated that each of the four band-pass filters 132, 134, 136 and 138 is identical and the filtering is arranged to be applied to central diode signal samples obtained from the four quadrants A, B, C and D.

While the illustrated embodiment indicates that the diagonal slope signals are calculated based upon low pass filter, absolute, differential diagonal diode signals, it would be possible to obtain such signals without differential processing. Then, for example, with regard to quadrants A and C, the slope signal would comprise the band-pass filtered value of the absolute value of the sum of the signals from quadrants A and C.

Also, the signals from the four quadrants A, B, C and D can be normalized on individual slope signals.

From Fig. 4, and the description above, it will be appreciated that the digital DPD signal is calculated on the basis that:

$$DPD = LPF \quad [(DIFF(A_N+B_N))\,(A_N - B_N) - (DIFF(D_N + C_N))\,(D_N - C_N)]$$

Such an arrangement proves advantageous since it can provide for an accurate radial tracking error signal even if defects such hair scratches and black dots are apparent on the surface of the disc since the arrangement advantageously compensates for unwanted amplitude changes of the diagonal signals that can arise if a defect such as those described above occurs.

It will of course be appreciated that the amplitudes of the diagonal signals A + C and B + D change significantly when encountering defects such as "hair scratches" on the surface of the disc. The radial error signal, then based on a digital DPD processing, will disadvantageously produce an unstable and large positive error signal when the hair scratches are encountered. Through the normalization of the individual diode signals in accordance with an embodiment such as that illustrated in Fig. 4 on the diagonal slope signals, or indeed on the slopes of the signals themselves, the

amplitude changes of the diagonal signals due to defects such as hair scratches can be compensated for, or removed so as to improve the performance of the performance of the radial tracking DPD signal. A damaged, for example, scratched, disc can therefore advantageously still be used with the present invention.

Through use of the sum of diagonal opposite diode pair signals to control the individual amplitude of the two diodes as illustrated in Fig. 4, normalization on the slopes of individual diode signals can be achieved. Then unwanted amplitude changes of the diagonal signals due to the above-mentioned defects can be overcome so as to provide for an improved performance with regard to digital radial tracking via a DPD signal.

As will therefore be appreciated, the methods and arrangements of the present invention, as illustrated in the non-limiting embodiments of Figs. 2, 3 and 4 allow for an advantageous reduction in costs and improved simplification and performance for monitoring tracking in an optical disc system.

CLAIMS

1. A differential phase detection arrangement for monitoring the tracking of an optical disc, comprising a four-quadrant photo detector from which first and second signals are derived, phase shift or differentiating means arranged for phase shifting or differentiating the first of the photo detector signals, multiplying means arranged for multiplying the phase shifted or differentiated signal with the second of the said photo detector signals so as to produce a signal for deriving a Differential Phase Detection signal.

2. An arrangement as claimed in Claim 1, and including first and second band pass filtering means for band-pass filtering the first and second signals derived from the photo detector.

3. An arrangement as claimed in Claim 1 or 2 and including a low pass filter means arranged for receiving the signal derived from the multiplying means.

4. An arrangement as claimed in Claim 1, 2 or 3, and including means for deriving a normalising signal from the phase shifted or differentiated signal.

5. An arrangement as claimed in Claim 4, wherein the said normalising signal is derived by way of a low pass filter.

6. An arrangement as claimed in Claim 1, 2, 3, 4 or 5, wherein the band pass filter arrangement comprises a high pass filter having a cutoff frequency not higher than the frequency of I14.

7. An arrangement as claimed in any one or more of the preceding claims, wherein the band pass filter arrangement includes a low pass filter having a cutoff frequency not lower than the frequency of I3 or I2.

8. An arrangement as claimed in any one or more of Claims 1 to 7, wherein the first of the signals derived from the four quadrants photo detector comprises a digitized RF signal A+B+C+D.

9. An arrangement as claimed in Claim 8, wherein the said second of the signals derived from the four quadrants photo detector means comprises a digitized push-pull diagonal signal A+C-B-D.

10. An arrangement as claimed in any one or more of Claims 1 to 7, and wherein separate digitized signals are obtained from each of the four quadrants A-C of a four quadrants photo detector.

11. An arrangement as claimed in Claim 10, and including adder means for adding the signals from quadrants A and D so as to provide the said first signal derived from the photo detector, subtracting means for determining the difference between the signals from quadrants A and D so as to provide the said second signal from the photo detector, further adder means for adding the signals from quadrants B and C so as to provide a third signal for delivery to third band-pass filtering means, and a further subtracting means for determining the difference between signals from B and C for delivery to fourth band-pass filtering means.

12. An arrangement as claimed in Claim 11, and including further phase shift or differentiated means for phase shifting or differentiating the signal derived from the third band-pass filtering means, and including further multiplying means arranged for multiplying the phase shifted or differentiated signal from the further phase shift or differentiated means with the signal derived from the fourth band-pass filtering means.

13. An arrangement as claimed in Claim 12, and including subtracting means for determining the difference between the signals from the said multiplying means and the said further multiplying means so as to arrive at a differential phase detection signal.

14. An arrangement as claimed in Claim 13, and including a low pass filter means through which the signal arising from the difference between the signals from the said multiplying means and the said further multiplying means is delivered.

15. An arrangement as claimed in Claim 13 or 14, and including adder means for the phase shifted or differentiated signals from the first and third band pass filtering means so as to provide an absolute function of the differentiated RF signals.

16. An arrangement as claimed in Claim 15, and including low pass filter means for receiving the said absolute value of the differentiated RF signals.

17. An arrangement as claimed in Claim 10, wherein the separate digitized signals comprise normalized signals.

18. An arrangement as claimed in Claim 17, wherein the sum of the outputs from diagonally opposite pairs of the four-quadrants photodetector is employed to control the signal output from each quadrant within the diagonally opposite pair of quadrants.

19. An arrangement as claimed in Claim 18, and arranged such that the slope of the signal representing said sum is determined and the signal output from each of the said quadrants is normalized against the slope signal.

20. An arrangement as claimed in Claim 18, wherein the slope of the signal representing the said sum is determined by band pass filtering the absolute sum of the outputs from the pair of diagonally opposite quadrants.

21. An arrangement as claimed in Claim 18, wherein the slope of the signal representing the said sum is determined by band pass filtering the absolute value of the differential of the sum of the outputs from the pair of diagonally opposite quadrants.

22. An arrangement as claimed in Claim 19, 20 or 21, wherein the signals from both pairs of diagonally opposite quadrants of the four-quadrant photodetector are normalized against respective slope signals.

23. An arrangement as claimed in any one or more of Claims 17 to 22, wherein the said first signal comprises the differential of the sum of the normalized signals from quadrants A and B.

24. An arrangement as claimed in Claim 23, wherein the said second signal comprises the difference between the normalized signals from quadrants A and B.

25. An arrangement as claimed in Claim 23 or 24 and further including means for determining the differential of the sum of the normalized signals from quadrants C and D.

26. An arrangement as claimed in Claim 25 and further including means for determining the difference between the normalized signals from quadrants C and D.

27. An arrangement as claimed in Claim 26 and including multiplying means arranged for multiplying the said differential and difference values obtained from the normalized signals from quadrants C and D.

28. An integrated circuit including an arrangement as defined in any one or more of Claims 1-27.

29. An optical disc drive including an arrangement as defined in any one or more of Claims 1-27.

30. A recording and/or playback device for use with an optical disc and including an optical disc drive as defined in Claim 29.

31. A method of monitoring tracking in an optical disc drive comprising the steps of deriving signals from a four quadrants photo detector, phase shifting or differentiating a first of the said signals derived from the photo detector,

multiplying the resulting phase shifted or differentiated signal with a second of the said signals derived from the photo detector so as to arrive at a DPD signal.

32. A method as claimed in Claim 31 and including the step of band-pass filtering the signals derived from the photo detector.

33. A method as claimed in Claim 31 or 32, and including the step of low pass filtering the signal resulting from the said multiplication.

34. A method as claimed in Claim 31, 32 or 33, and including the step of deriving a normalising signal from the phase shifted or differentiated signal.

35. A method as claimed in Claim 31, 32, 33 or 34, wherein the step of deriving signals from the four quadrants photo detector comprise the steps of deriving a digitized RF signal A+B+C+D.

36. A method as claimed in any one or more of Claims 31 to 35, wherein the step of deriving signals from the four quadrants photo detector includes the step of deriving a digitized diagonal push-pull signal A+C-B-D.

37. A method as claimed in Claim 31, 32, 33 or 34, wherein the steps of deriving signals from the four quadrants photo detector comprises the steps of deriving separate signals from each of the four quadrants A, B, C, D.

38. A method as claimed in Claim 37, and including the steps of band-pass filtering signals comprising the combination of signals from detector quadrants A+D and B+C, and band pass filtering difference signals A-D and B-C.

39. A method as claimed in Claim 38, and including the step of phase shifting or differentiating the band-pass signals A+D and B+C and multiplying the phase shifted differentiated signals with the band pass signals A-D B-C respectively.

40. A method as claimed in Claim 39, and including the step of determining the difference between the results of the aforesaid multiplication so as to arrive at a differential phase detection signal.

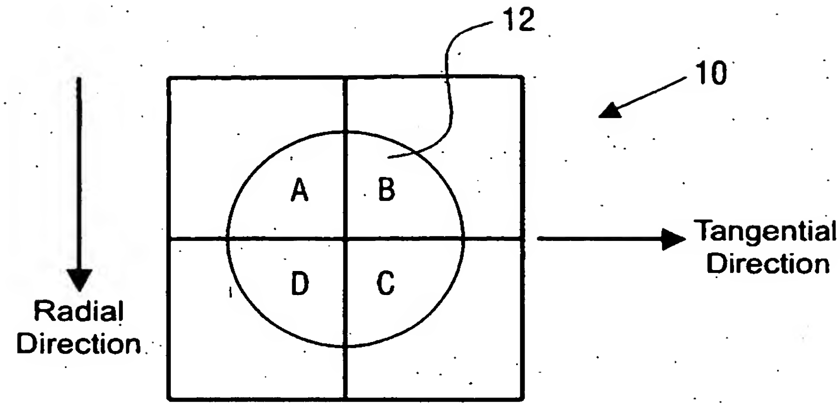
41. A method as claimed in Claim 40, and including the steps of adding the band-pass signals A+D and B+C so as to derive a normalization signal.

42. A method as claimed in Claim 37, and including the step of normalizing the separate digitized signals.

43. A method as claimed in Claim 42 and including the step of controlling the signal output from each quadrant within a pair of diagonally opposite quadrants of the photodetector by means of the sum of the outputs from the diagonally opposite pairs of the photodetector.

44. A method as claimed in Claim 43, and including the steps of determining the slope of the signal representing the said sum, and normalizing the signal output from each of the said quadrants against the said slope signal.

45. A method as claimed in Claim 44, wherein the signals from both pairs of diagonally opposite quadrants of the four-quadrant photodetector are normalized against respective slope signals.


12
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A
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Radial Direction
Tangential Direction

FIG.1

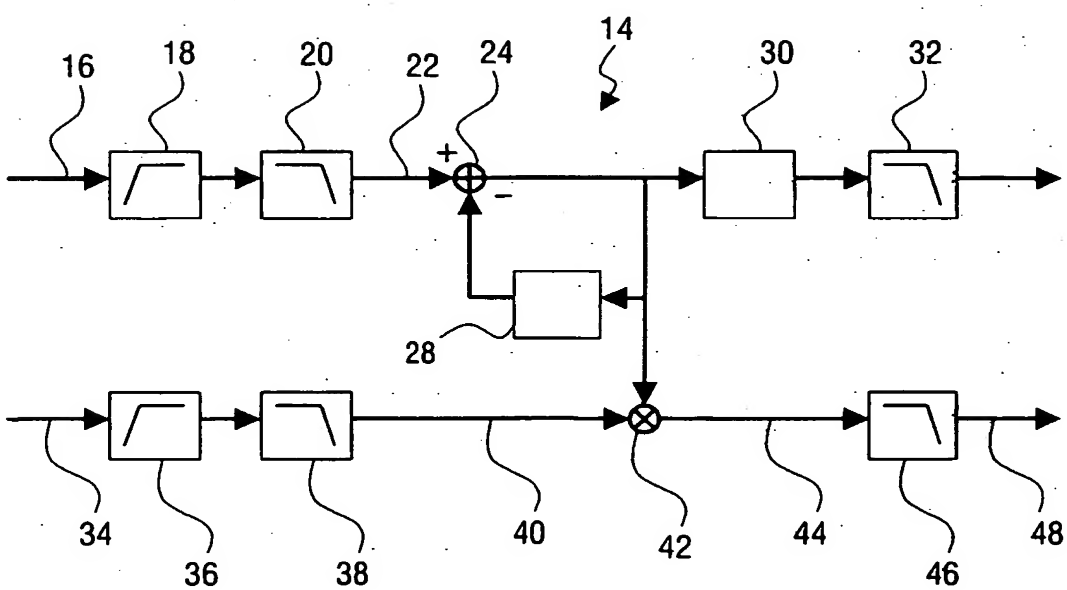
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FIG.2

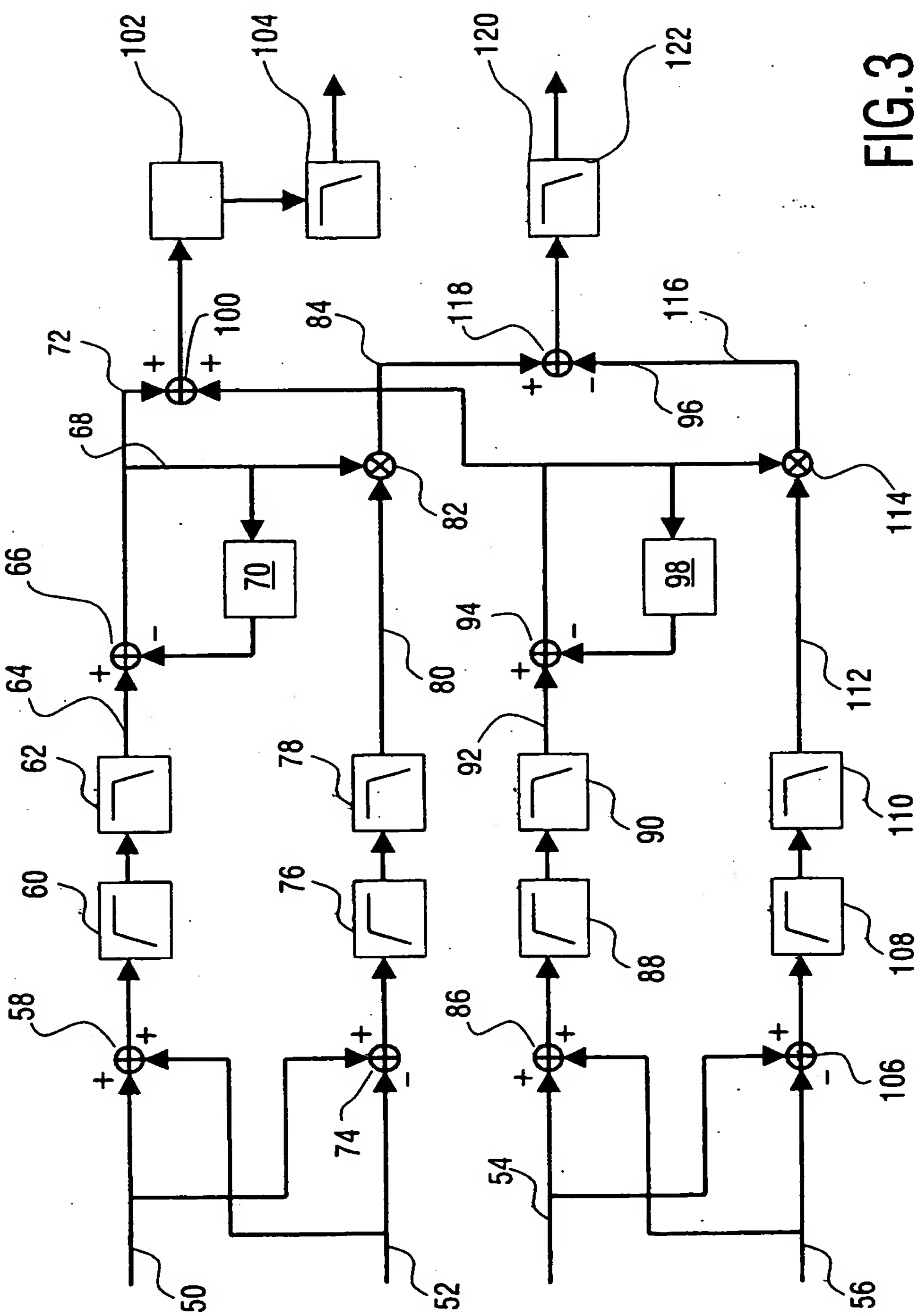
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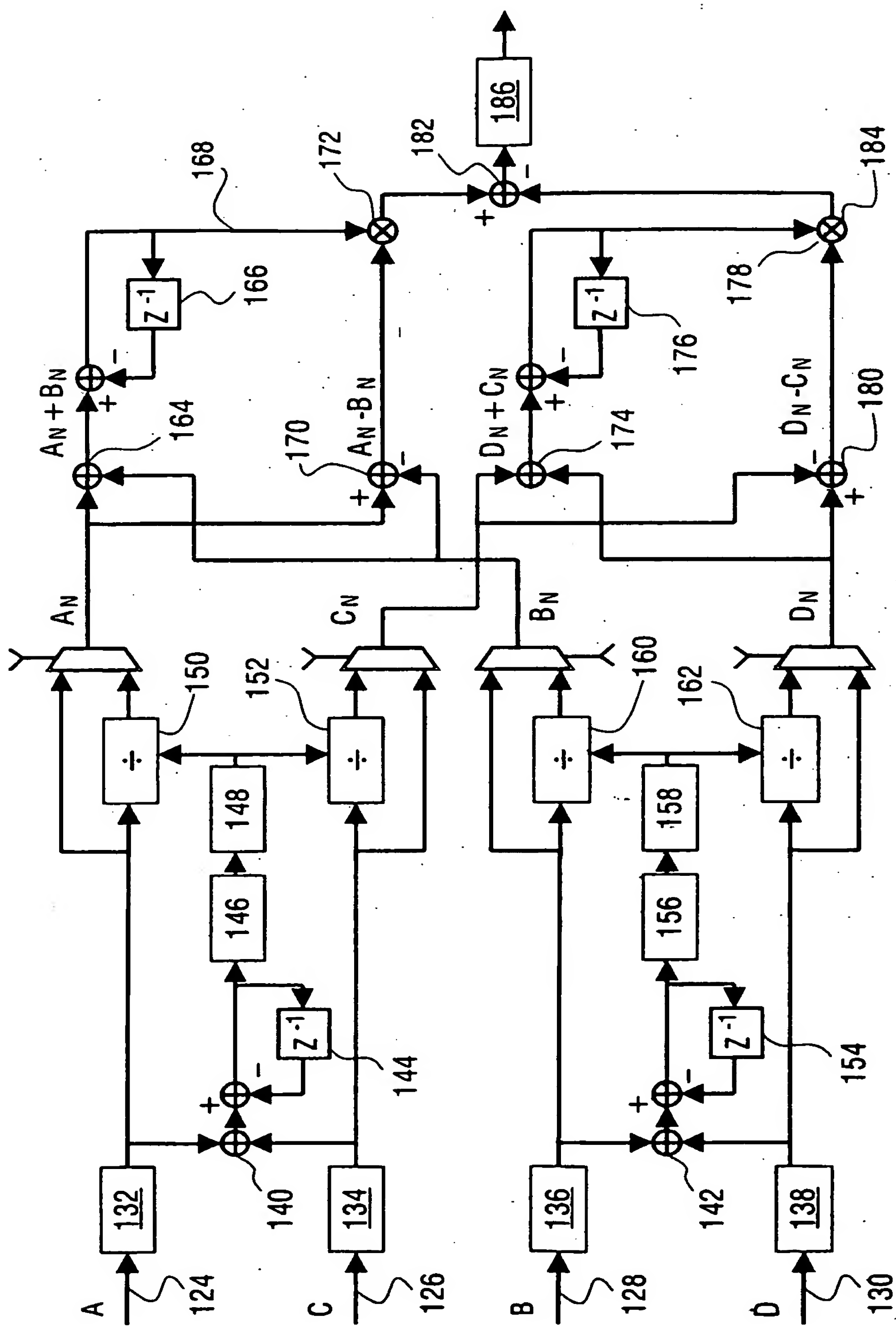
FIG.3

3/3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164
170
174
180
A_N+B_N
A_N-B_N
D_N+C_N
D_N-C_N
Z^{-1}
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FIG.4

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB2004/001176

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G11B7/09

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G11B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 583 209 A (BIERHOFF MARTINUS P M) 15 April 1986 (1986-04-15) column 3, line 19 - column 7, line 28; figures	1,3-5, 8-10, 28-31, 33-37
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[X] Further documents are listed in the continuation of box C.

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19 August 2004	30/08/2004

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB2004/001176

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 5 808 979 A (ISHIBASHI HIROMICHI ET AL) 15 September 1998 (1998-09-15) column 3, line 27 - column 10, line 29; figures	1-45
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